which depend on the method used to cut the conductive rods to form the conductive buttons. For example, if a laser is used to do the cutting then the end contacts typically have a non-planar shape due to the heating effect caused by interaction of the laser radiation with the conductive wiring. As an example, the end contacts **47** and **48** in FIG. 3 have a surface curvature (e.g., spherical or elliptical) with an associated surface concavity toward the conductive button **38**. A spherical or similar shape for the end contacts is desirable if the end contacts are to be mated with a substrate conductive pad that is susceptible to being damaged by contact with sharp or pointed end contacts. For example, if the conductive pad is a flat, gold pad on a surface of an electronic module, the end contact should have a spherical or similar shape so that the resultant stress on the pad will be low enough so as not to damage the gold pad, but high enough to make good electrical contact with the gold pad.

If the cutting is done mechanically, however, the cutting introduces a mechanical shear and creates a chisel effect with a chisel angle that is related to the helical angle of the conductive wiring. As an example, FIG. 12 illustrates a cross-sectional view of a conductive button **88** having a dielectric core **89** and conductive wiring **90** helically wound circumferentially around the dielectric core **89**, and an outer dielectric jacket **92** around the conductive wiring **90**. The conductive wiring **90** has end contacts **91**, wherein the end contacts **91** have been generated by mechanical cutting such as with a shearing or EDM process. Due to the mechanical cutting, the end contacts **91** tend to have a chisel-like planar shape. Other shapes may be generated for the end contacts by varying the cutting method as well as the cutting details for a given cutting method. For example, the cutting device itself could be moved during the cutting process so as

to vary the cutting direction (e.g., cutting height) as the cutting is occurring. To illustrate the usefulness of the chisel-like shape, a solder-coated pad has a surface oxide that needs to be penetrated by the end contacts. If the conductive wiring is cut mechanically, the resultant end contact tends to be chisel-like and sharp enough to penetrate the surface oxide and lock into the solder surface so as to contact the conductive structure of the pad .

For a conductive rod having conductive wiring made of a non-noble metal or of a non-noble metal having a noble metal plating thereon, the end contact **86** (see FIG. 11) formed by cutting may be plated, after cutting, with a noble metal plating to provide corrosion resistance.

Another technique that affect the shape of other characteristics of an end contact is to cut the conductive rod (e.g., the conductive rod **60** of FIG. 10) at a node (i.e., intersection or point of crossing) of two wires of the conductive wiring, such as at a node **61** of the intersection of the conductive wiring **53** and **56** in FIG. 5. An end contact resulting from cutting the conductive rod at such a node, in comparison with an end contact not formed at such a node; would provide a larger end contact, would be stiffer, would common the two intersecting or crossing wires together, and would give a better metallurgical coupling (i.e., a mechanically stronger coupling) between the two wires. Note, however, that cutting through the two intersecting or crossing yields only one end contact instead of two end contacts.

The multiple (e.g., a plurality) of end contacts at each end of a conductive button provides conductive redundancy, so that if one or more end contacts should fail (e.g., become conductively decoupled from a substrate pad), then conductive coupling would nonetheless persist due to the conductive functionality of other end contacts that have not failed.

For example, a dielectric core of approximately 10 mils (i.e. 0.010 inches) having a circumference of approximately 31 mils can have 10 wires of 1 mil diameter in each helical direction with a spacing of approximately 3 mils. These wires can provide 10 to 20 end contacts depending how the end contacts are formed.(e.g., depending on how many of the end contacts are formed at nodes, as discussed *supra*).

Another feature of using the conductive buttons of the present invention to conductively couple two substrates is that the conductive buttons are less susceptible to thermal stress-induced failure than are solder interconnects (e.g., solder balls, solder columns, etc.) that conductively couple the two substrates. In particular, the conductive buttons facilitate more flexible substrate structures with a higher fatigue life than do solder interconnects, because the helically wound conductive wiring material (e.g., BeCu, beryllium, nickel, etc.) of the present invention is not as subject to as much shear as is solder in a solder interconnect. In particular, the helical winding does not give rise to a pure shear but rather to a bending stress, which results in a lower stress level in the wires. Thus, fatigue damage is accumulated at a slower rate per cycle inasmuch as the helical wiring pattern distributes the stresses in different directions relative to the axial direction (i.e., the direction **54** or **55** in FIG. 3).

As stated *supra*, the electrical structure of FIG. 3 facilitates repairing or upgrading in the field because substrates **32** and **34** can be readily decoupled by release or removal of the force **46**. This feature results from the fact that the conductive buttons **38** in FIG. 3 are not permanently attached to the pads **35** and **33** of the substrates **34** and **32**, respectively. Another embodiment of the present invention is to permanently attach the conductive buttons **38** to the pads **33** prior to